CEWES Major Shared Resource Center

MSRC

CEWES MSRC/PET TR/99-29

Oceanographic Model Visualization with the Interactive Structured Time-Varying Visualizer

by

Michael A. Chupa
Robert J. Moorhead

05h00599

Work funded by the DoD High Performance Computing Modernization Program CEWES Major Shared Resource Center through

Programming Environment and Training (PET)

Supported by Contract Number: DAHC94-96-C0002
Nichols Research Corporation

Oceanographic Model Visualization with the Interactive Structured Time-Varying Visualizer (ISTV)

Michael A. Chupa
Robert J. Moorhead
Engineering Research Center for
Computational Field Simulation
Mississippi State University
{*chupa* | *rjm* }*@erc.msstate.edu*

1 April 1999

Abstract

The visualization of multigrid, multiresolution ocean models with the Mississippi State University ERC Interactive Structured Time-Varying Visualizer (ISTV) application is described as applied to a Wave Action Model (WAM) simulation of the 1998 El Niño event produced at the CEWES MSRC. Data manipulations required for visualization are described, along with development work in ISTV designed to provide built-in support for WAM visualizations. Other related ISTV work undertaken during contract year 3 is also discussed.

1 Overview of the Interactive Structured Time-varying Visualizer

The Interactive Structured Time-Varying Visualizer (ISTV) is a high-performance visualization tool to support users of environmental computational models. ISTV was developed at the Mississippi State University Engineering Research Center, and was first released in February, 1996; more recent development work was possible with funding by the CEWES and NAVO MSRC PET programs.

ISTV is a visualization system for time-varying, three-dimensional, structured data sets. It was developed for the large data sets generated by high-resolution ocean circulation models, but the software was designed as a general package which could be used on data from other domains. For example, most of the ocean model data are on grids which are rectilinear in latitude and longitude, but this is not a requirement of the system. In fact, ISTV can handle data on time-varying curvilinear grids. ISTV has been used to visualize data from a wide variety of domains other than ocean model data, such as aerospace simulations, electromagnetic simulations, and medical data.

ISTV allows for time-synchronized visualization of multiple, time-varying independent data sets in a single view volume. For example, atmospheric conditions and topography are common inputs to an ocean model and they may each be defined on a grid which is different from the model's output. ISTV can display all three of them in the same image, providing the capability to visually examine the relationships between the data.

ISTV treats each data set as a logical four-dimensional grid (time plus space) which can have any number of scalar values defined at each grid point. These values can be stored in a file or derived as needed by the software. The division of each data set into multiple files is hidden from the user. Convenient controls are provided for selecting a region of interest from the 3-D space and animating this subset over a specified period of time. The animations may be captured to disk for later replaying.

ISTV was originally designed to support users of the Navy Layered Ocean Model at the Naval Research Laboratory, Stennis Space Center, but also supports a variety of other data formats, including PLOT3D. Recent PET funding allowed the extension of ISTV to support visualization of the Wave Action Model and Computational Hydrodynamics in 3-D (CH3D) in use at the Waterways Experiment Station, Vicksburg, MS.

1.1 Data Access Architecture

ISTV employs a logical grid file (LGF) interface to data in their native format; this allows data to be physically stored in the most convenient manner while still allowing ISTV to view the data as a single dataset. The LGF architecture also provides a consistent data interface to the higher-level visualization routines. Derived variables are also specified within the LGF structure, allowing transparent user access to fields stored on disk or computed on-the-fly. The derived variables are supported via a calculator module, which can be customized to provide support for new models; calculated variables can also provide support for a variety of data projections, e.g., mapping latitude/longitude data onto a sphere.

1.2 Visualization Capabilities

Using a Motif GUI with an OpenGL 3-D drawing area, as shown in Figure 1, ISTV provides a comprehensive set of visualization mappings in both the scalar and vector domains. Scalar mappings provided include conventional color mappings, contours, and isosurface extraction. A color wheel mapping supports visualization of vortical structures (e.g., ocean eddies). Vector mappings include tufts and streamlines, using both individual seed points and rakes. For time-varying flows, pathlines and streaklines are also supported.

ISTV also provides basic multiresolution capabilities by providing subsetting on read functionality, allowing modest desktop machines to visualize very large datasets at reduced resolution. A sparse display model is used when the 3-D window contents are in motion.

Multiple datasets with varying temporal and spatial resolutions may be visualized simultaneously by reading several LGF files.

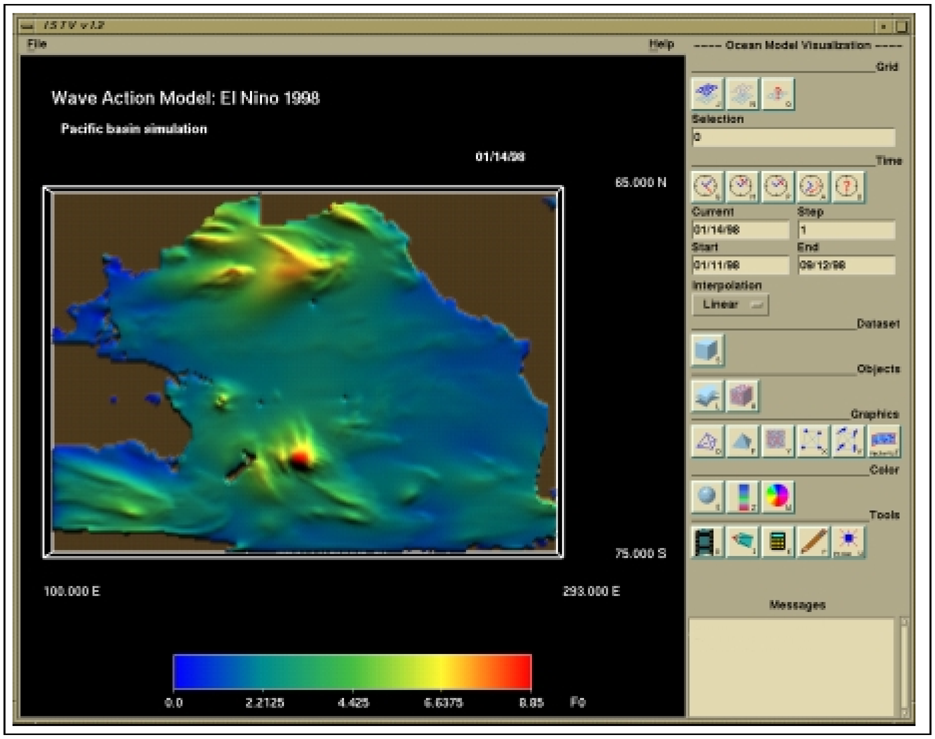

Figure 1: ISTV Graphical User Interface.

Still image and batch-mode animation generation is supported, and 2D text annotation is supported within the 3-D window; this text annotation provides capabilities for time-stamping frames in animations.

1.3 Distributed Visualization Capability

ISTV can be configured to run with two distinct processes: a data server and visualization front-end, using the MPICH message-passing library. The data server was originally configured to run on a Cray server with the visualization front-end on an SGI workstation, but has also been used as a separate process on multiprocessor SGIs and Suns.

ISTV's approach to data access, coupled with the distributed visualization support, enables visualization of high-resolution model output; with subsampling, and region of interest selection, this makes visualization possible on modest desktop machines, even with very large datasets.

2 Visualization of Wave Action Model with ISTV

ISTV was used to create images and animations of WAM simulation data. These data were produced in three separate domains; the temporal extent of the hourly data was from 1 Jan 1998, 1900 hours to 20 Jan 1998, 0000 hours. The spatial extents of the three domains are listed in the chart below.

	ires	jres	lat. start	lat. end	long. start	long. end	Δ
Basin	194	141	75 S	65 N	100 E	293 E	$1°$
Region	57	77	31 N	50 N	230 E	244 E	$1/4°$
Subregion	133	73	32 N	35 N	238.5 E	244 E	$1/24°$

Table 1: WAM El Niño simulation spatial extents

The fields computed on each grid include significant wave height, wave mean frequency, wind direction, drag coefficient, spectra of total sea, mean wave direction, friction velocity, wave peak frequency, and normalized wave stress.

2.1 Visualization Issues

The output format from WAM is in the form of MAP files, which contain all of the fields for a 12-hour range of output data. Mike Stephens of the CEWES ITL had previously processed the El Niño simulation MAP files for visualization. The primary improvement was the removal of the unformatted FORTRAN block counts, leaving us with raw binary files. However, these files remained in Cray binary (64-bit) format, so for visualization on our IEEE SGI machines at the ERC we wrote another preprocessing filter that runs on SGIs which took the Cray binary files and wrote out a series of IEEE 32-bit floating point format files. To further simplify data access, each of the scalar fields embedded within the MAP files was written to a separate disk file. This is not a requirement of ISTV, but did simplify the storage organization.

In order to provide animations of the El Niño simulations, we needed to construct a sequence of hourly data from the MAP files. This proved challenging due to the way WAM data is laid out on disk. The top-level directory timestamped 98010918 contains MAP files with timestamps 9801100600 through 9801120600, each containing 12 hourly dumps of data. For example, the MAP file timestamped 9801100600 (10 Jan 1998, 0600 hours) contains data for timestamps 9801091900 through 9801100600, the previous 12 hours. The overlapping of some time step data is accounted for by the WAM convention of allowing for both "nowcasts" as well as forecasts. In order to construct a correct sequence of files for visualization, ISTV requires each data file to have a unique time index set. Since we had written the individual fields to separate disk files, the process of writing the LGF files by hand would have been time-consuming and prone to errors. A package was written that automates the generation of ISTV LGF files by recursively scanning a directory containing the MAP file data written with our Cray to IEEE binary filter.

2.2 Animation Production

Using the standard ISTV toolset, we were able to produce several animations of the significant wave height field for each of the three domains provided. However, the land masking convention used in the MAP file output, which wrote zeros on inactive grid locations, proved problematic, since many scalar fields could contain zero as a valid value on the computed portion of the grid. Further work with WAM would be enhanced by using a land mask value well out of range of any scalar fields of interest.

In addition to the separate animations from the basin, region and subregion simulations, animations were also produced with all three datasets displayed simultaneously using a spherical mapping of the latitude/longitude grid as shown in Figure 2.

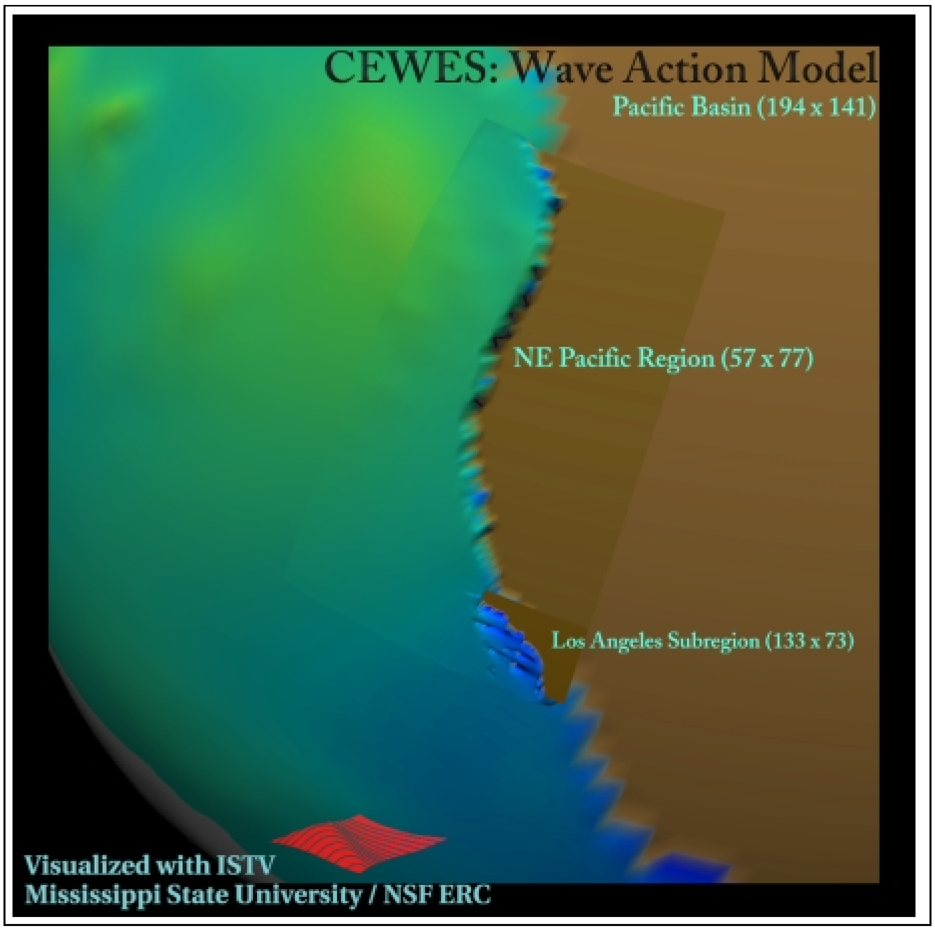

Figure 2: WAM multiple grid visualization.

2.3 Colorwheel visualization

Additions to ISTV's calculator module allow for the visualization of the wind forcing vector field. The MAP files contain wind heading and magnitude fields, which are then internally translated back to two vector components for use in the colorwheel visualization module as shown in Figure 3.

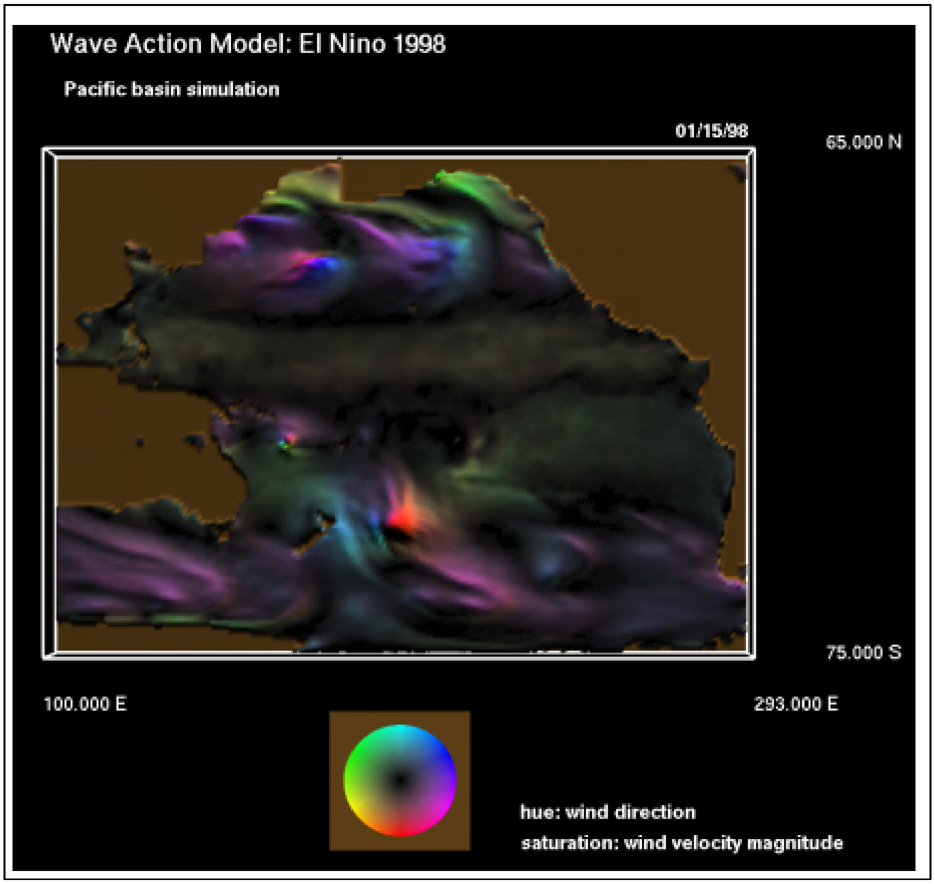

Figure 3: WAM colorwheel visualization of forcing winds.

3 Other ISTV Work

During this grant period, other ISTV development work was carried out to port ISTV to the Solaris (SPARC) platform for use with Sun's new OpenGL workstations. In addition, numerous performance enhancements and bug fixes were applied to the vector visualization module. This module was also documented and added to the tutorial materials available with ISTV.

To facilitate working with very large datasets, ISTV was also reconfigured for use on 64-bit architectures; the supporting HDF and MPICH libraries were also recompiled for use with ISTV.

A day-long short course on ISTV was presented at CEWES in January, 1999 in the Training and Education Facility at the CEWES MSRC.

4 Acknowledgments

The WAM datasets used in our visualization work were provided by Robert Jensen of CEWES.

Preprocessing of the WAM MAP files was done by Michael Stephens of the AHPCRC at the CEWES.

Cass Everitt of the MSU ERC worked on the binary conversion routines to translate the CRAY C90 data into IEEE format for visualization.